Measurement of sedentary behaviour in population health surveys: a review and recommendations

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Background: The purpose of this review was to determine the most valid and reliable questions for targeting key modes of sedentary behaviour (SB) in a broad range of national and international health surveillance surveys. This was done by reviewing the SB modules currently used in population health surveys, as well as examining SB questionnaires that have performed well in psychometric testing. **Methods:** Health surveillance surveys were identified via scoping review and contact with experts in the field. Previous systematic reviews provided psychometric information on pediatric questionnaires. A comprehensive search of four bibliographic databases was used to identify studies reporting psychometric information for adult questionnaires. Only surveys/studies published/used in English or French were included. **Results:** The review identified a total of 16 pediatric and 18 adult national/international surveys assessing SB, few of which have undergone psychometric testing. Fourteen pediatric and 35 adult questionnaires with psychometric information were included. While reliability was generally good to excellent for questions targeting key modes of SB, validity was poor to moderate, and reported much less frequently. The most valid and reliable questions targeting specific modes of SB were combined to create a single questionnaire targeting key modes of SB. **Discussion:** Our results highlight the importance of including SB questions in survey modules that are adaptable, able to assess various modes of SB, and that exhibit adequate reliability and validity. Future research could investigate the psychometric properties of the module we have proposed in this paper, as well as other questionnaires currently used in national and international population health surveys.

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ABSTRACT

Background: The purpose of this review was to determine the most valid and reliable questions for targeting key modes of sedentary behaviour (SB) in a broad range of national and international health surveillance surveys. This was done by reviewing the SB modules currently used in population health surveys, as well as examining SB questionnaires that have performed well in psychometric testing.

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48

49 **INTRODUCTION**

50 Sedentary behaviour (SB; sitting, and activities that require very low energy expenditure and
51 done while sitting or reclining [1]) is a unique risk factor for several chronic diseases and
52 mortality [2-6]. Recognition and interest in this risk factor has prompted the inclusion of
53 measures of SB in population health surveillance surveys around the world [7, 6, 8-10]. While
54 self-report tools provide information about mode and domains of SB, little is known about their
55 validity (the degree to which the questionnaire measures what it claims to measure) and
56 reliability (the degree to which a questionnaire can produce consistent and reproducible results)
57 [5, 11]. Habitual patterns of SB can be measured objectively using accelerometers and
58 inclinometers, but these methods are often too time or resource intensive for inclusion in
59 population level health surveys and studies. Further, these objective methodologies are unable to
60 distinguish between different domains (e.g. occupational/school, transportation, leisure,
61 domestic) and modes (e.g., TV, computer use, reading, car driving) of SB. This is an important
62 issue, given that some modes of SB appear to be more consistently associated with indicators of
63 poor health than others. For example, the relationship between total SB and health outcomes is
64 often weaker than for some specific modes of SB, especially TV viewing and total screen time
65 [12, 5, 13]. A smaller body of research suggests that sedentary transportation may also show
66 deleterious associations with health [14], whereas reading has been shown to be benign or even
67 beneficial [5, 15]. It is important to note, however, that further research is still needed to identify
68 whether these associations are independent of other confounding factors such as food
69 consumption and socio-economic status.

While two recent systematic reviews have examined the reliability and validity of SB questionnaires in pediatric populations [16, 17], no reviews have compared the psychometric properties of SB questionnaires in adults, and none have examined those used in population level surveys. Therefore, the objectives of the present review were to: 1) summarize the available self-report tools for assessing the most common modes of SB including TV viewing, computer use, total screen time, reading, sedentary transportation, and total SB in national and international population surveillance surveys; and, 2) to identify the most valid and reliable questions/questionnaires for assessing total and individual modalities of SB. We aim to provide readers with practical and evidence-informed information to support the development of future population health surveys.

METHODS

Inclusion and Exclusion Criteria

The present review focuses on questionnaires used in national and international surveys, as well as those that have undergone formal testing for validity and/or reliability. Activity diaries and ecological momentary assessment tools were excluded from the review due to their low level of practicality within the context of population health surveys. Surveys and any associated validity/reliability testing had to be in English or French to be included in this review.

National/International Survey Questions

To be included in the present review, surveys had to assess SB (e.g. sitting/reclining and an energy expenditure ≤ 1.5 metabolic equivalents [1]), as opposed to the lack of physical activity

(often referred to as physical inactivity). Questionnaires were excluded if we were unable to obtain complete wording for SB items within the questionnaire. Questionnaires used to assess SB in multiple regions in an individual country were considered national in scope, while those that assessed SB in multiple countries were considered international. Surveys that examined only a specific location or region within a country were excluded, as were surveys that examined special populations (e.g. those with a specific disease or condition).

Studies Evaluating Questionnaire Reliability and Validity

To be included in the present review, individual studies required at least 30 participants per analysis to ensure adequate power (80%, $\alpha = 0.05$) to identify a moderate correlation ($r = 0.50$) between self-report and objective measures.

Search Strategy

National/International Survey Questionnaires

National and international survey questionnaires were identified via the reference databases of the authors and through a scoping review using the Google search engine. An email was also sent to members of the Sedentary Behaviour Research Network (SBRN; a research network of over 1,100 scientists with an interest in SB, www.sedentarybehaviour.org) asking for help in the identification of additional national and international surveys with questions or components measuring SBs.

Studies Evaluating Questionnaire Reliability and Validity

Similar to the search for national and international SB questionnaires, studies examining the validity and reliability of SB questionnaires were first identified via personal reference databases, then through email correspondence with SBRN members. During this process, we identified two recent systematic reviews that had summarized the reliability and validity of SB questionnaires in children and youth [16, 17]. These reviews provided a high quality summary of the current evidence and were used to inform our discussion on reliability and validity of SB questionnaires among the pediatric population.

We were unable to identify any similar review of SB questionnaires among adults. As a result, we performed a search of the literature to identify relevant studies in adults (aged >18 years). A search strategy (**Supplemental Table 1**) was carried out in four electronic databases including: Ovid MEDLINE(R) In-Process (1946 - November Week 1 2016); Ovid PsycINFO (1806 to November Week 1 2016); EBSCOhost SPORTDiscus (1830 to November 2016); and EBM Reviews - Cochrane Database of Systematic Reviews 2005 to November 1, 2016). The search sought to identify studies that reported on the validity and/or reliability of a self-report tool (i.e., questionnaire, survey) that measures SB.

Assessment of Reliability and Validity

In the context of this review, a SB measurement tool with high reliability consistently provides similar estimates of SB across multiple trials. Test-retest reliability is often assessed in SB research using an intraclass correlation coefficient (ICC). Cronbach's α is used to test for internal consistency of a tool. Both measures produce values ranging from 0 to 1; where 1 represents perfect reliability and consistent results and 0 represents no reliability or inconsistent results. It is

138 therefore ideal to have an ICC and Cronbach α as close to 1 as possible, with anything over 0.75
139 considered excellent. In the present review, an ICC between 0.60 and 0.74 was considered good,
140 an ICC between 0.40 and 0.59 was considered fair, and an ICC <0.40 was considered poor [18].
141
142 Identifying whether a self-report tool is able to accurately quantify SB is referred to as criterion
143 validity. Validity of a self-report SB measure is often assessed against objective measures (e.g.,
144 activPAL™, accelerometer, direct observation). The majority of validation studies report a level
145 of correlation between two measures (e.g., questionnaire and accelerometer-measured sedentary
146 time) and similar to the ICC, a correlation coefficient closer to 1 was used to indicate a stronger
147 relationship. We also examined, when available, mean differences and levels of agreement
148 between the self-report and objective measures.
149
150 Validity and reliability statistics were extracted in the format provided by the individual studies.
151 Inclinometry was considered the gold standard for total SB and sitting time (e.g. activPAL),
152 which has been shown to have the highest sensitivity for distinguishing between sitting and
153 standing [19, 20]. Accelerometry was also considered as a criterion measure to assess validity.
154 Although accelerometry provides an objective measurement of time spent sedentary, it is not as
155 sensitive as inclinometry for measuring SB because of its inability to distinguish between
156 stationary standing and sitting and may therefore misclassify some standing time as SB [20, 19].
157 Inclinometry and accelerometry were not considered appropriate criterion standards for specific
158 SB modalities (e.g., TV time, reading). Rather, direct observation or detailed diaries/logs were
159 considered as useful measures for looking at the validity of questionnaires which measured
160 specific modalities of SB.

RESULTS

Sedentary Behaviour Questions used in National/International Surveys and Studies

The review identified a total of 16 pediatric and 18 adult national/international surveys and large national epidemiological studies assessing at least one modality of SB (**Supplemental table 1**). Pediatric surveys meeting inclusion criteria were used in 38 countries, while we identified adult surveys used in 22 countries. Surveys included as few as one question (e.g., Global Physical Activity Questionnaire [GPAQ], European Prospective Investigation into Cancer and Nutrition-Potsdam Study [EPIC]), and as many as 12 questions (Children's Leisure Activities Survey [CLASS]) related to SB. Although all included questionnaires employed English or French versions, many had also been translated into other languages for specific populations. There was a considerable lack of published literature reporting on psychometric testing for the majority (pediatric = 63%, adult = 56%) of the questionnaires used in national and international surveys for all age groups. SB modalities varied across questionnaires, with TV viewing time being the most frequently assessed (pediatric = 100%, adults = 72%). Computer and/or video game time were also frequently assessed, especially among pediatric populations (pediatric = 88%, adults = 39%). Fewer surveys included questions related to reading (pediatric = 44%, adults = 50%) or sedentary transport (pediatric = 13%, adult = 33%). The wording of questions varied across surveys, although often in relatively trivial ways (e.g., reporting in hours versus minutes). Many (pediatric = 38%, adults = 44%), but not all, of the surveys referred to a specific time period for recall (e.g., the past week, four weeks, three months, or year), and reminded participants to focus on a “typical” or “usual” day or week in that time period. Some surveys focused on hours per day of each SB mode, whereas others focused on hours per week. Some surveys asked about an

184 average of the days of the week, while others had separate questions for school/work/week days
185 and weekends. Several (pediatric = 63%, adults = 28%) of the surveys separated their questions
186 for each modality of SB (e.g., Canadian Health Measures Survey [CHMS], ISCOLE, HBSC,
187 etc). Some surveys employed the use of a grid or list of SB modalities (e.g. COMPASS) and
188 required participants to enter daily time for each SB.
189
190 **Reliability and Validity of Individual Questionnaires**
191 The reliability and validity of individual questionnaires has been summarized in **Supplemental**
192 **table 3**. Items/questions from these questionnaires can be found on the SBRN website
193 (http://www.sedentarybehaviour.org/files/?get=Spreadsheet,%20March%2028,%202017.xlsx).
194 We identified 14 questionnaires from previous systematic reviews [16, 17] which have
195 undergone psychometric testing in a pediatric population. Through our search strategy (Figure
196 1), we identified 35 adult questionnaires with published psychometric properties (multiple papers
197 reported on the psychometric testing of the same questionnaire) that examined the validity and/or
198 reliability of adult SB questionnaires. Included questionnaires contained as few as one question
199 (e.g., GPAQ, Yale Physical Activity Survey for Older Adults [YPAS], Past Year Physical
200 Activity Questionnaire, Past-Week Modifiable Activity Questionnaire [PWMAP], Modified
201 MONICA Optional Study on Physical Activity Questionnaire [MOSPA-Q]) [21-26], and as
202 many as 23 (Adolescent Sedentary Activities Questionnaire [ASAQ] [27]) items related to SB.
203 Although we identified studies examining the reliability of questions related to key SB
204 modalities, only the measurement of total SB and total sitting time employed appropriate
205 criterion standards for validity.
206

TV viewing

Among preschool-aged children and youth, both the Preschool-aged Physical Activity Questionnaire (Pre-PAQ) (ICC = 0.70-0.88, 95% CI: not reported [NR]) [28] and the proxy-report questionnaire used in the Health, Eating and Play Study (HEAPS) (ICC = 0.78, 95% CI: 0.69-0.84) [29], had excellent levels of reliability. Testing of the COMPASS questionnaire in children in grades 9-12 yielded a fair ICC of 0.56 (95% CI: NR), and a Cronbach's α of 0.74 [30], which was the highest identified in this age group. Among adults, the Sedentary Behavior Questionnaire (SBQ) demonstrated excellent reliability for weekday (ICC = 0.86, 95% CI: 0.76, 0.92) and for weekend (ICC = 0.83, 95% CI: 0.72, 0.90) TV viewing [31], while the Past Week Modifiable Activity Questionnaire (PWMAQ; ICC = 0.67, 95% CI: 0.61, 0.71) [24], Salmon SB questionnaire (ICC = 0.82, 95% CI: 0.75, 0.87) [32]/Measure of Older Adults Sedentary Time (MOST; ICC = 0.76, 95% CI: 0.62, 0.86) [33] and Sedentary, Transportation and Activity Questionnaire (STAQ; ICC = 0.79, 95% CI: 0.61, 0.89) [34] also had very reliable questions for TV time. These questionnaires varied in both the wording of the questions and in response categories, suggesting that a variety of approaches provide reliable results for TV viewing. Few studies have compared appropriate objective measures of TV-specific SB to self-reported TV time. Among children, the Youth Risk Behaviour Survey TV time questions were validated against a 7-day TV log and exhibited a moderate correlation ($r = 0.46$) [35]. Among adults, the Salmon SB questionnaire was poorly correlated ($r = 0.3$, $p<0.01$) with 3-day logs for measures of self-reported TV time [32].

Computer, Tablet and Video Game Use

Compared to TV viewing, relatively few (pediatric = 19%, adult = 11%) questionnaires have undergone psychometric testing for items related to computer use. Among pre-school aged children and youth, the Pre-PAQ proxy-report questionnaire demonstrated high levels of test-retest reliability for computer and video game playing (ICC = 0.82-0.85, 95% CI: NR) [28]. The COMPASS questionnaire had slightly lower, but still good levels of reliability on questions related to computer and video game use (ICC = 0.65, 95% CI: NR, Cronbach's $\alpha = 0.79$) and surfing the internet (ICC = 0.71, 95% CI: NR, Cronbach's $\alpha = 0.84$) among high school students [30]. Among adults, the Gennuso et al. SB questionnaire (ICC = 0.93, $p<.001$) [36] and the Measure of Older Adults' Sedentary time (MOST) (ICC = 0.79, 95% CI: 0.65, 0.86) [33] had very high reliability for the question targeting computer and internet use. Similarly, the SBQ [31] has shown high reliability (weekday: ICC = 0.83; 95% CI: 0.72, 0.90, weekend: ICC = 0.80; 95% CI: 0.67, 0.88) for a question focusing on computer and video game use. The Marshall Sitting Time Questionnaire asks a single question targeting home-based computer use and has demonstrated good reliability (women: weekday ICC = 0.63, 95% CI: 0.52, 0.71; weekend ICC = 0.72, 95% CI: 0.64, 0.79, men: weekday ICC = 0.62, 95% CI: 0.48, 0.73; weekend ICC = 0.59, 95% CI: 0.44, 0.71) [37]. Finally, the French version of the STAQ asks a question on time spent in all forms of computer, tablet and video game use, and has shown to have good reliability (ICC = 0.64, 95% CI: 0.38, 0.80) [34].

Among adults, the Salmon SB questionnaire used three-day logs to validate self-reported computer use ($r = 0.60$) [32]. Only one study was found to compare a specific modality of SB with an appropriate objective measure. The Workplace Computer Use Questionnaire compared

self-reported occupational computer use to direct observation and found they were moderately correlated (r = 0.41, p = 0.001), reliability was not assessed [38].

Total Screen Time

The ASAQ reported excellent reliability (grade 6 girls: ICC = 0.76, 95% CI: 0.57, 0.87 to grade 8 boys: ICC = 0.90, 95% CI: 0.82, 0.95) for the measure of total screen time, which was calculated as the sum of all time watching TV, videos, DVDs, and using a computer for fun or homework.[27] The STAQ (ICC = 0.70, 95% CI: 0.48, 0.84) [34] and Domain-Specific Last 7-d Sedentary Time Questionnaire (SIT-Q-7d) (average day ICC = 0.61, 95% CI: 0.53, 0.67) [39] also demonstrated good reliability for total screen time calculated as the sum of individual screen-based behaviours in adults.

Reading

We were unable to identify any studies examining the reliability or validity of reading questions in children and youth. Although the ASAQ includes a question on reading, to our knowledge its reliability and validity have not been reported. In contrast, several questionnaires have undergone psychometric testing for items related to reading in adults. The Salmon SB questionnaire had the best level of reliability for reading with an ICC of 0.78 (95% CI: 0.69, 0.84)[32]. The MOST (adapted from Salmon's questionnaire; ICC = 0.74, 95% CI: 0.51, 0.86) [33], SBQ (weekday: ICC = 0.64, 95% CI: 0.44, 0.78, weekend: ICC = 0.48, 95% CI: 0.24, 0.67) [31] and Sit-Q-7D (ICC = 0.59, 95% CI: 0.51, 0.66) [39] had slightly lower reliability, although it should be pointed out that there were only minor differences in wording across the three questionnaires, and all ICCs fell in the “fair to excellent” range. Reading time from the Salmon SB questionnaire was

validated against a three-day log and a low correlation between the two measures (r = 0.20) was reported [32].

Stationary Transportation

The reliability of the Pre-PAQ proxy-report questionnaire ranged from poor to good (ICC = 0.31-0.63, 95% CI: NR) for a question focusing on the amount of car time over the past week in pre-school aged children [28]. The ASAQ question focusing on time spent in a car, bus or train has good reliability (average ICC = 0.61) in boys and girls in grades 6, 8 and 10, but performed significantly better in girls than boys (e.g., grade 10 girls ICC = 0.93, 95% CI: 0.85, 0.97 vs. grade 10 boys: ICC = 0.25, 95% CI: -0.31, 0.57) [27]. Among adults, the International Physical Activity Questionnaire (IPAQ; r = 0.81-0.91) [40] and the Salmon SB questionnaire (ICC = 0.85, 95% CI: 0.79, 0.89) [32] had excellent reliability for weekly passive transport. The SBQ also has excellent reliability for both weekday (ICC = 0.76, 95% CI: 0.61, 0.86) and weekend days (ICC = 0.72, 95% CI: 0.56, 0.83) [31].

Total Sedentary Behaviour

Total SB was the only outcome for which we could find comparisons to appropriate objective standards in any age group. Among children and youth, estimated after-school SB (a composite score of TV, computer and cell-phone time) from the Youth Activity Profile (YAP) was highly correlated (r = 0.75, P <0.001) with total sedentary time from the Sensewear armband [41]. The Activity Questionnaire for Adults and Adolescents (AQuAA; r = 0.23, P >0.05),[42] COMPASS (r = 0.20; p<0.05) [30] and Physical Activity and Sedentary Behavior Assessment Questionnaire (PASBAQ) (r = 0.20-0.27) [43] reported low correlations between self-reported total SB

297 (calculated as the sum of all SB modalities) and hip-worn accelerometers in pediatric
298 populations. Importantly, the COMPASS questionnaire also presented with high levels of test-
299 retest reliability (ICC = 0.79, 95% CI: NR) [30]. We did not identify any studies examining the
300 validity of questions of total sitting time in children and youth, though most of the items for total
301 SB are likely to be accomplished while sitting.
302
303 Among adults, validation studies have looked at single item estimates of sitting time, or have
304 generated a composite score from a number of items to estimate total SB. The Past-day Adults'
305 Sedentary Time (PAST) and Past-Adults' Sedentary Time - University (PAST-U) questionnaires
306 had the highest measures of validity (PAST: r = 0.57, 95% CI: 0.39, 0.71, PAST-U: r = 0.63,
307 95% CI: 0.44, 0.76) between a total of sum of SBs and sedentary time from the activPAL [44,
308 45]. The questionnaire from the AusDiab3 Study (r = 0.46, 95% CI: 0.40, 0.52) [46] and the
309 Madras Diabetes Research Foundation Physical Activity Questionnaire (MPAQ; r = 0.48, 95%
310 CI: 0.32, 062) [47] also had moderate agreement with objective measures. In addition, the
311 MPAQ also had excellent reliability for all sitting time (ICC = 0.81, 95% CI: 0.78, 0.84) [47].
312 The Salmon SB questionnaire had excellent reliability for total SB (ICC = 0.79, 95% CI: 0.71,
313 0.85) [32]. Even though the IPAQ is one of the most frequently used tools for self-reported SB, it
314 relates poorly to objective measures. The validity of the IPAQ has been examined in multiple
315 studies using accelerometers and inclinometers, with correlations generally ranging between 0.22
316 and 0.50 (depending on study sample), but with correlations for test-retest reliability generally
317 above 0.70 [48, 49, 40, 50].
318
319 **DISCUSSION**

The purpose of the present review was to summarize the questions used to assess SB in national and international population surveillance surveys, and to identify the most valid and reliable questions for measuring both total SB and specific sub-domains and modes of SB. Although we identified a large number of national/international surveys, as well as a relatively large number of questionnaires with published results from psychometric testing, we found there was relatively little overlap between the two groups. Questions used in large population health surveys have typically not undergone appropriate evaluation with respect to validity or reliability, whereas questionnaires that have undergone this psychometric testing have typically not been used in larger national/international surveys.

Of the various modalities of SB, available evidence suggests that in general, self-reported total SB, TV viewing, computer use, and total screen time are negatively associated with physical and psychosocial health indicators in both children and adults [5, 12, 51]. Although it has been the focus of relatively few studies, the opposite relationship is observed for reading, which is associated with higher levels of academic achievement in children, and increased longevity in adults [5, 15]. It is unclear whether these relationships are due to physiological mechanisms, or due to confounding via other variables (e.g., socio-economic status), though at present there is little evidence to suggest that reading *per se* has a negative impact on health. Limited evidence suggests that transportation-related and occupational sedentary time may also be associated with poor health outcomes [14, 52]. However, to our knowledge there is no evidence to suggest that the health impact of occupational sedentary time is different from that of total sedentary time, or that the impact of occupational computer use is different than that of non-occupational computer use. A sum of all modalities of SB is important for providing prevalence estimates of sedentary

343 time; however, specific modalities of SB associate differently with health and are useful for
344 surveillance. Given their consistent and deleterious associations with health indicators, and high
345 prevalence of daily use, we suggest that TV time, computer time and total screen time are the
346 self-report modalities of SB of greatest importance to include in population health surveys. We
347 also suggest that if feasible, time spent in sedentary transport and reading are worth measuring
348 and may provide insightful information.
349
350 As noted earlier, objective measurement tools (e.g., inclinometers and accelerometers) can only
351 be used to test the validity of questions, or series of questions, aimed at estimating *total*
352 sedentary time. The studies included in this review show poor validity in total SB when various
353 questionnaires are assessed against objective measures. Similarly, Hidding *et al.* reported an
354 absence of SB questionnaires that are both reliable and valid for use among children and youth
355 [16]. Important to consider is that although accelerometers and inclinometers can help to validate
356 sitting time questionnaires, they are unable to tell if a specific question accurately assesses
357 specific modalities of SB (e.g., TV viewing, computer use, etc.). The questionnaires that
358 performed best when compared to objective measures, specifically the PAST [44] and PAST-U
359 [45], asked participants to record their time spent in nine different modes of SB, the sum of
360 which provided a measure of total SB time. It is recognized, however, that a nine-item
361 questionnaire is likely prohibitively long for inclusion in population surveillance surveys that are
362 designed to obtain broad-level indicators of health across a large number of areas. The review
363 was unable to locate any studies that examined the validity criterion of questions measuring
364 screen time, reading or sedentary transportation. This is not surprising given the inability of
365 objective measurement devices to delineate one type of SB from another. Thus, it is unclear

whether answers to these questionnaires represent an accurate depiction of an individual's time spent in highly prevalent modalities of SB. It is also important, to identify the main limitation of this paper; the absence of a systematic and comprehensive search strategy. It is therefore, likely that there are questionnaires/surveys that have not been captured in the review.

Importantly, while the validity of most self- and proxy-report SB health surveillance surveys are unknown, they still appear to provide useful measures of risk associated with health behaviours. In fact, self-reported SBs tend to be more strongly associated with health outcomes than objective measures, especially among children and youth [5, 53, 54]. This suggests that it may be the behaviours done while sedentary (e.g., watching TV vs. reading) that are more important than total SB [54]. In addition, recall of specific SBs like screen time is likely easier than recalling all instances of sitting time throughout the day. Further, the available evidence does not suggest that SB questionnaires are invalid; rather that the validity of most questionnaires, especially those used in national/international surveillance surveys, have not been assessed against appropriate criterion measures. As noted elsewhere, objective and subjective measures of SB provide different, but complementary, information [55]. Therefore, it is recommended that population health surveys consider employing both types of measures where feasible (i.e., both an inclinometer and a questionnaire).

In contrast to validity, we identified several questionnaires with acceptable reliability for the assessment of various SB domains in both adults and children. Reliability is a key factor for population surveillance surveys where the assessment of SBs over time are important to monitor the prevalence of this risk factor, as well as to evaluate changes resulting from population-level

interventions [56]. While it would be ideal to have access to questionnaires that are known to be both valid *and* reliable, it is still useful and important to know that reliable options do exist for the measurement of important SB modalities. It is important to consider that a tool that has shown to be reliable at one time point, may lose its relevance and require updating with the emergence of new modes of SB as a result from changes in technology and its use. We recognize that reliability results did vary substantially between measures. Some of this variation may be a result of the population in which reliability of the questionnaire was assessed (e.g. general vs. special population) and the context (e.g., study looking only at reliability and validity of questionnaire vs. assessing reliability and validity within a pre-existing study).

Additional factors for consideration

In addition to validity and reliability, there are several other factors of relevance when attempting to determine the ideal means for assessing SB in population surveillance surveys. For example, it has been noted that individuals are increasingly engaged in "multi-tasking", whereby they are participating in multiple forms of SB simultaneously [57]. For example, individuals may be reading or playing a video game on a tablet while also watching TV. If the total time spent doing each of these activities is simply summed together, this can result in inflated estimates for total screen time or total SB [58]. Some of the questionnaires identified in this review (e.g. the MOST questionnaire) address this issue using a pre-amble to ask respondents to only identify the "main" form of SB during a given time period. We recommend that future surveys incorporate this methodology.

411 It is important that surveillance surveys assess the types of SBs that reflect those which are most
412 used in the population and recognize that these may change over time. For example, many
413 individuals now watch television programming over internet streaming services such as Netflix
414 or YouTube in addition to (or instead of) traditional cable or satellite TV. One option to ensure
415 that the most current SB modes are assessed is through the consistent use of relatively generic
416 questions for each SB modality, with detailed examples provided beneath that can be updated as
417 new forms of SB emerge.
418
419 We also recommend that population surveillance surveys ensure that the questions used to
420 measure SB are in a format that can assess whether the population is meeting relevant public
421 health guidelines. For example, Canadian guidelines recommend that school-aged children and
422 youth accrue no more than two hours per day of recreational screen time [59]. It is therefore
423 important that population health surveys provide information in a format which can be used to
424 assess whether or not an individual is meeting such guidelines. In particular, allowing
425 respondents to enter their response as a specific continuous number (e.g. hours and minutes per
426 day or week), or providing a large range of individual options (e.g., 0, 30 minutes, 1 hour, 2
427 hour… 6+ hours) allows this to be easily calculated. These approaches have been used by several
428 questionnaires with high levels of reliability in both children and adults (e.g., COMPASS, SBQ).
429 Importantly however, scaled response categories preclude the ability to determine specific
430 durations of SB for those in the highest category (e.g. if a person answers “6+ hours” you will
431 not know if they engaged in 6 hours versus 12 hours of screen time). This can complicate data
432 analysis, as well as in the interpretation of “average” time spent in a SB across a population.
433

Finally, with respect to population surveillance surveys, it is important that they remain consistent, whenever possible, to provide information on secular trends in SBs over time. The questions used to assess SB vary widely across national and international surveys, often change over time, and do not always target the same domains of SB (e.g., screen time, leisure, occupational, transport, etc.). These issues preclude meaningful comparisons over time, or across countries and regions, and diminish the usefulness of the information provided by these surveys/questionnaires for researchers, health behaviour interventionists and policy makers. Thus, it is recommended that population health surveys should use consistent questions from year-to-year whenever possible.

Suggested SB Module

Table 1 provides a suggested SB module that we developed using modified individual questions from other questionnaires with acceptable reliability. Examples have been provided in brackets for some questions; these can be updated over time as new popular modes of SB emerge (e.g. a new Smartphone or internet streaming service). We have proposed individual questions for time spent using screens, watching TV, using computers (including tablets, smart phones, and video games), reading, in sedentary transportation, and total sitting time. To address SB guidelines for children and youth, the caveat *"during your free time"* can be added for questions related to screen time for children and youth, but not adults [59]. For each question, answers are reported in a continuous fashion using hours and minutes per week. This approach allows the researcher to easily determine whether an individual is meeting or exceeding public health guidelines, which can be difficult (and sometimes impossible) when using categorical variables. As noted above, this is the approach used by several questionnaires that performed well on test-retest

457 reliability. The preambles from the MOST and SBQ questionnaires have also been adapted in an
458 attempt to minimize the impact of multitasking.
459
460 Reading was included given that it is the only form of SB consistently associated with positive
461 health indicators [15]. At present it is unclear whether the health impacts of reading on a screen-
462 based device differ from those of reading a physical book. Studies that have shown associations
463 between reading and academic achievement or longevity tend to simply ask how much time
464 people spend reading books or magazines, without specifying the device used [15, 60]. As books
465 and magazines are likely to be increasingly read on screen-based devices, more research will be
466 needed to determine if this has any impact on the relationship between reading and health, which
467 may also differ based on the specific screen-based device being use (e.g. lit screens may have a
468 more detrimental impact on sleep than non-lit screens [61]). For now, it is suggested to include
469 wording similar to that used in the 2015 CHMS [62], which includes reading done using both
470 physical books and electronic devices.
471
472 The questions are listed in order of their importance, based on their associations with health
473 outcomes. The options also recognize the need for population surveys that include SB measures
474 may have limited space for questions regarding a single health behaviour. Therefore, if there is
475 room for only one question, then question 1 (Screen time) should be used. If there is room for
476 two questions, then questions 2 (TV time) and 3 (Computer time) should be used; this allows the
477 researcher to also calculate total screen time (i.e. will provide a response for question 1). If the
478 survey allows for more items, we suggest adding questions 4 to 6 sequentially.
479

To date, many SB questionnaires have separated weekdays from weekend days. This is especially true in the pediatric population, where the majority of questionnaires separate week (or school) and weekend days. This format is recommended as individuals often have very different and sometimes counter-intuitive schedules on weekdays versus weekend days. In line with this practice, we have suggested that each question be asked twice; once for weekdays, and once for weekend days.

CONCLUSIONS

This review aimed to describe SB modules that have been commonly used in national and international surveys. We also aimed to identify the most reliable and valid tools currently available to assess SB. Unfortunately, we were unable to identify a single tool that met all of our criteria. As such, we have recommended a new module, based on the best available evidence that can be modified to suit the needs of individual surveys. Future research could investigate the psychometric properties of the proposed module, as well as other questionnaires currently used in national and international population health surveys.

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772

Figure 1(on next page)

Flow diagram of literature search for adult questionnaires

SB = sedentary behaviour, SB = Sedentary Behaviour Research Network

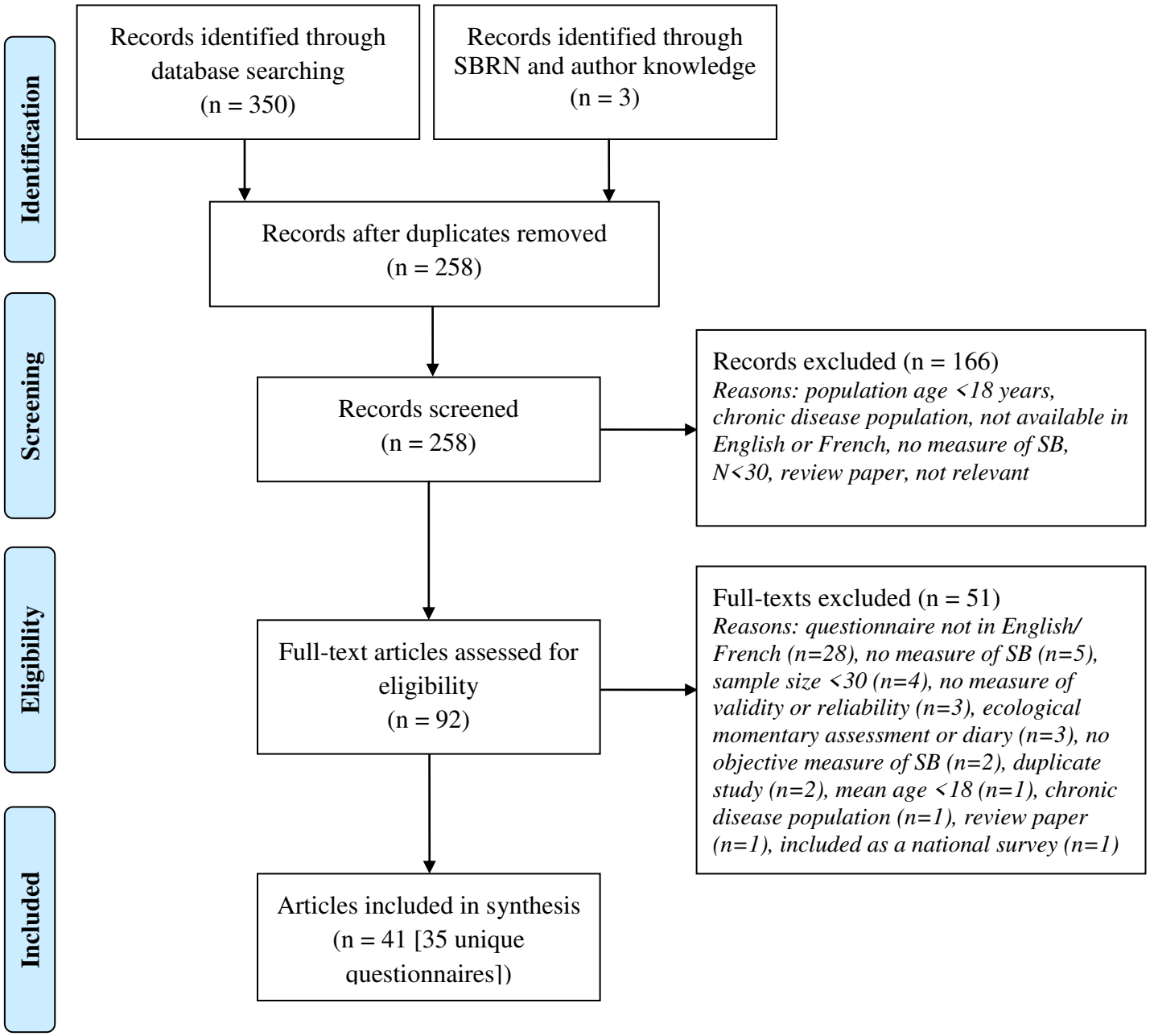
Identification
Screening
Eligibility
Included
Records identified through database searching (n = 350)
Records identified through SBRN and author knowledge (n = 3)
Records after duplicates removed (n = 258)
Records screened (n = 258)
Records excluded (n = 166)
Reasons: population age <18 years, chronic disease population, not available in English or French, no measure of SB, N<30, review paper, not relevant
Full-text articles assessed for eligibility (n = 92)
Full-texts excluded (n = 51)
Reasons: questionnaire not in English/ French (n=28), no measure of SB (n=5), sample size <30 (n=4), no measure of validity or reliability (n=3), ecological momentary assessment or diary (n=3), no objective measure of SB (n=2), duplicate study (n=2), mean age <18 (n=1), chronic disease population (n=1), review paper (n=1), included as a national survey (n=1)
Articles included in synthesis (n = 41 [35 unique questionnaires])

Table 1(on next page)

Suggested sedentary behaviour module

Table 1 *S*uggested sedentary behaviour module

*The following questions are about activities you/your child did over the **past week while sitting or lying down**. Do not count the time you/they spent in bed sleeping or napping.*

For each of the following activities only count the time when this was your/their main activity. For example if you/they are watching television and surfing the internet, count it as television time or computer time, but not as both. [adapted from MOST questionnaire]

On a typical WEEKDAY/WEEKEND DAY in the past week, how much time do you/your child spend sitting or lying down and… [adapted from SBQ and MOST questionnaires]

SEDENTARY ITEM	TIME		SOURCE	MODIFICATIONS
1. Watching TV or using a computer, tablet or smartphone or [*for children and youth only:* during your/their free time?]* *(Count time watching videos, playing computer games, emailing or using the Internet. Do not include time spent on a computer at work or at school.)* *Note: this question can be omitted if questions 2 & 3 are used instead.	__ hours	_____ minutes	CHMS	iPad is no longer specifically referenced in question.
2. Watching television or videos [*for children and youth only:* during your/their free time?] *(Count time spent watching television, DVDs and online*	__ hours	_____ minutes	MOST	Addition of "during your free time", and information in parentheses.

videos)				
3. Using a computer [*for children and youth only:* during your/their free time?] *(Count time spent on things such as computers, laptops, Xbox, PlayStation, iPod, iPad or other tablet, or a smartphone, YouTube, Facebook or other social networking tools, and the Internet).*	__ hours	_____ minutes	MOST	Added "during free time", removed "internet" from main question, placed examples in parentheses.
4. During the last 7 days, how much time did you usually spend sitting on a week/weekend day? *(Include time spent at school or work, at home, while doing course work, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television).*	__ hours	_____ minutes	IPAQ	Information from preamble moved to parentheses.
5. Sitting and driving in a car, bus, or train.	__ hours	_____ minutes	SBQ	N/A
6. Sitting reading a book or magazine *(Include reading done using electronic formats. Include time spent reading as part of your homework, but do not include time spent reading at work, during class time, during transportation or while exercising).*	__ hours	_____ minutes	SBQ and CHMS	N/A

Information in square brackets is provided for the reader, but should not be included on the final questionnaire.